

7.4A DELAY LINE AND MUTUAL COUPLING CONSIDERATIONS
FOR MST RADAR ANTENNA ARRAYS

J. W. Brosnahan

Tycho Technology, Inc.
Boulder, CO 80306

Basic antenna theory states that the field radiated from an antenna array is equal to the sum of the currents flowing in each element of the array. The feedline distribution system must guarantee the proper amplitude and phase of the current for each element of an array. This sounds easy, just make sure that the difference in electrical lengths of the feedlines to the elements equals the desired phase angle. But this isn't necessarily correct. The current (or voltage) delay in a transmission line is equal to the transmission line electrical length in only a few special cases, when the transmission line is terminated in its characteristic impedance or when the transmission line's electrical length is a multiple of 90 degrees.

The impedance of any element in an array is dependent on the coupling between that element and the other elements. This mutual coupling is dependent on the phase relationship of the current in the element in question and the other elements. If the phase of the current is changed in one element, then the other elements can show a change in their input impedances, and therefore not terminate the transmission line properly, resulting in an additional change of phase in the other elements.

If an MST array is to be steered during operation by changing the delay line lengths, attention should be paid to this mutual impedance effect. Typical MST radar arrays consist of Yagis or coaxial-collinear (BALSLEY and ECKLUND, 1972) elements. To determine the mutual coupling effect with coaxial-collinear elements, an experiment was performed using two coaxial-collinear elements with 1/2 wavelength spacing between elements 1/4 wavelength above a ground plane.

The impedance of one 26-element coaxial-collinear antenna was measured while open circuiting and short circuiting a second 26-element antenna 1/2 wavelength away. Virtually no impedance change was noted. The second element was then completely removed and still no impedance change was noted. This lack of mutual coupling between coaxial-collinear antennas can be explained by the following. Elements 1/4 wavelength above ground with half wavelength spacing have relatively low mutual coupling. In addition, the input impedance of the element is so dominated by the 26 dipoles electrically connected together that mutual coupling effects at 1/2 wavelength spacing is minimal. A possible third factor is that the dipoles in a coaxial-collinear element are non-resonant because of the velocity factor of the coaxial cable used makes the dipoles 0.33 wavelength long.

It appears that coaxial-collinear arrays with 1/2 wavelength spacing and antennas 1/4 wavelength above ground are very forgiving because of the lack of the mutual coupling problem. Experience with Yagi elements indicates that they are not as forgiving to changing feedline lengths.

Yagi arrays require special attention to the array feedline system to minimize the mutual coupling problem. Figure 1 shows a beam-steering and power-divider scheme for the array of 64 Yagis as shown in Figure 2. This feed system utilizes delay lines of 1/4 wavelength multiples only. Figure 3 shows the required feedline phases for the various patterns. These delay lines will ensure proper current phase at each element, with changing feedline lengths. But current amplitude can vary because of the impedance changes with changing feed-

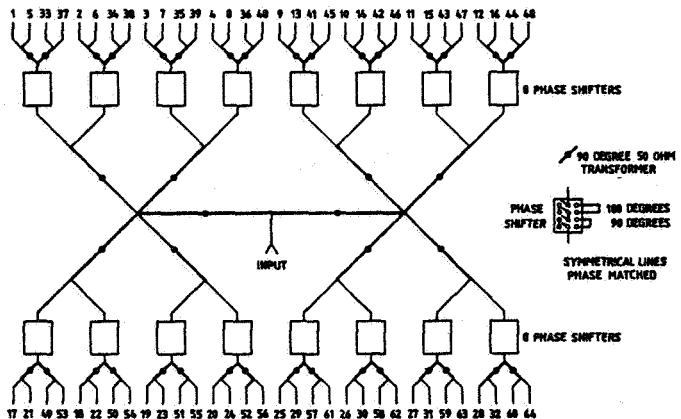


Figure 1. Power divider and beam steering delay system.

line lengths. With delay lines that are multiples of $1/4$ wavelength, a spacing between elements of from 0.75 to 1.5 wavelengths provides a main beam lobe of between 19.5 degrees and 9.6 degrees. Antenna spacing is chosen to provide a null at the zenith, provide a main lobe at between 10 and 20 degrees and minimize sidelobes. In addition, spacing should be selected to minimize the mutual coupling effect.

Individual element feedlines are chosen to be odd multiples of $1/4$ wavelength to utilize the constant current properties of quarter-wave transmission-line transformers. The constant current properties of a $1/4$ wavelength line are such that the current in a load at the end of a $1/4$ wavelength line is equal to the driving voltage divided by the characteristic impedance of the $1/4$ wavelength line regardless of the load impedance (JASIK, 1961). This will provide proper current drive at each individual element in the subgroups of four elements, and will help minimize the mutual impedance problems of the array.

(Of course, a delay line system with only 90 degree and 270 degree delays is possible, but all array patterns will have a dual beam when the array elements are driven with currents having only 180 degree phase differences.)

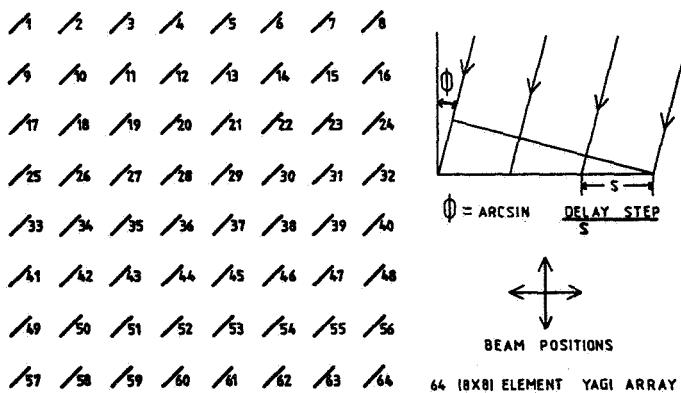


Figure 2. Yagi array orientation.

ELEMENT	VERT	DELAY LINE PHASE LAG IN DEGREES				NORTH SOUTH DUAL	EAST WEST DUAL
		NORTH	EAST	SOUTH	WEST		
1, 5, 33, 37	0	270	0	0	270	0	0
2, 6, 34, 38	0	270	90	0	180	0	180
3, 7, 35, 39	0	270	180	0	90	0	0
4, 8, 36, 40	0	270	270	0	0	0	180
9, 13, 41, 45	0	180	0	90	270	180	0
10, 14, 42, 46	0	180	90	90	180	180	180
11, 15, 43, 47	0	180	180	90	90	180	0
12, 16, 44, 48	0	180	270	90	0	180	180
17, 21, 49, 53	0	90	0	180	270	0	0
18, 22, 50, 54	0	90	90	180	180	0	180
19, 23, 51, 55	0	90	180	180	90	0	0
20, 24, 52, 56	0	90	270	180	0	0	180
25, 29, 57, 61	0	0	0	270	270	180	0
26, 30, 58, 62	0	0	0	90	270	180	180
27, 31, 59, 63	0	0	180	270	90	180	0
28, 32, 60, 64	0	0	270	270	0	180	180

Figure 3. Beam steering element phasing.

Currently, computer analysis is being conducted to optimize element spacing for the best pattern under all phasing conditions. Element spacings in the 1.0 to 1.25 wavelength range appear most promising. At these spacings the mutual coupling effect should be relatively low for typical size Yagis. An array of three of these 64 Yagis systems will be used in the Chung-Li, Taiwan, R.O.C. radar planned for completion in the third quarter of 1984 (BROSNAHAN et al., 1982).

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